Technical Report 1069

Team Situational Awareness Training in Virtual Environments: Potential Capabilities and Research Issues

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Members of small dismounted units face growing responsibilities and challenges in both combined arms combat and in contingency operations. Field training for these diverse missions is limited by cost and environmental factors. Virtual environment (VE) technology offers a potential complement to other training methods to meet the rapidly changing requirements for military training. This report provides an assessment, based on a review of the relevant research literature, of the capability of VE technologies, and strategies for their use, for training members of small dismounted units to acquire and maintain situational awareness. It summarizes the state of the art of research in the areas of situational awareness, team training, VE technology, and instructional strategies for simulation-based training. It identifies current and future challenges for providing situational awareness training to members of small dismounted units and makes recommendations for future research.

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FOREWORD

The U.S. Army has made a substantial commitment to the use of simulation for training, readiness, concept development, and test and evaluation. The current Distributed Interactive Simulation training system, SIMNET, and the next, the Close Combat Tactical Trainer, are both designed to provide realistic simulation of platform-based warfighting. They are not designed to provide realistic training for dismounted soldiers. Virtual Environment (VE) technology, which uses position tracking and real-time update of visual, auditory, and other displays (e.g., tactile) in response to the user's motions to give the user the sense of being "in" the environment, has the potential to improve simulation-based training for dismounted soldiers. One challenging area of research is matching U.S. Army training requirements with current and projected future VE capabilities.

This report provides an assessment of the capability of VE technologies, and strategies for their use, for training members of small dismounted units to acquire and maintain situational awareness (SA). It summarizes the state of the art of research in the areas of SA, team training, VE technology, and instructional strategies for simulation-based training. It identifies current and future challenges for providing SA training to members of small dismounted units.

The U.S. Army Research Institute for the Behavioral and Social Sciences, Simulator Systems Research Unit, conducts research with the goal of improving the effectiveness of simulators and simulations. The work described here is a part of ARI Research Task 2111, Virtual Environments for Combat Training and Mission Rehearsal.

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TEAM SITUATIONAL AWARENESS TRAINING IN VIRTUAL ENVIRONMENTS: POTENTIAL CAPABILITIES AND RESEARCH ISSUES

EXECUTIVE SUMMARY

Research Requirement:

Members of small dismounted units face growing responsibilities and challenges in both combined arms combat and in contingency operations. Field training for these diverse missions is limited by cost and safety factors. Virtual environment (VE) technology offers a potential complement to other training methods to meet the rapidly changing requirements for military training. The objective of this research effort was to assess the capability of VE technologies, and strategies for their use, for training members of small dismounted units to acquire and maintain situational awareness (SA).

Procedure:

Literature reviews were conducted in the following research areas: SA, team training, VE technology, and instructional strategies for simulation-based training. The Center for Army Lessons Learned (CALL), relevant field manuals, mission training plans, and training scenarios were used to identify current U.S. Army training challenges. Preliminary requirements for team SA training were derived from that literature and compared with the current capabilities of VE technology.

Findings:

The research literature suggests a number of requirements for providing SA training to members of small dismounted units. These include: a context as complex as the real-world situations; training in seeking information that conflicts with current understanding of the situation; experience in a variety of contexts; frequent practice to develop skills to automaticity; cross training; and training in coordination and communication skills. VE technology can provide complex, dynamic, immersive, multi-player environments which, at some level of fidelity, represent dismounted combat, and can incorporate instructional features to enhance training effectiveness. However, the current state of the art in affordable VE poses some problems for a highly realistic implementation of dismounted unit tasks: low visual resolution; highly artificial self-motion; limited behaviors of computer-generated forces (CGF); and gesture recognition systems of unknown quality. The extent to which this would preclude or limit the effectiveness of SA training is unknown. Research issues are identified, and a research approach suggested.

Utilization of Findings:

These findings will support the planning and conduct of research and technology demonstrations to improve simulations for dismounted soldier training. The identification of VE technology limitations can help industrial and academic facilities to prioritize and focus their research and development efforts.

TEAM SITUATIONAL AWARENESS TRAINING IN VIRTUAL ENVIRONMENTS: POTENTIAL CAPABILTIES AND RESEARCH ISSUES

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TEAM SITUATIONAL AWARENESS TRAINING IN VIRTUAL ENVIRONMENTS: POTENTIAL CAPABILITIES AND RESEARCH ISSUES

Introduction

The U. S. Army is engaged in a developing program using distributed interactive simulation (DIS) for combat training, military concept development, and test and evaluation. The early emphasis of this program has been on linking vehicle simulators, without providing for the training of dismounted soldiers (Knerr, Goldberg, Lampton, Witmer, Bliss, Moshell, & Blau, 1994). The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), supported by the University of Central Florida Institute for Simulation and Training (IST), has established a research program in Virtual Environment (VE) technology in order to investigate its application to training dismounted soldiers. The program goal is to "improve the U.S. Army's capability to provide effective, low cost training for Special Operation Forces and Dismounted Infantry through the use of VE technology and ICS (Individual Combatant Simulation)" (Knerr et al., 1994, pp. 10-12). The program focuses on the requirements for leader and individual performance in unit tasks, the determination of necessary characteristics for VE based ICS training, and the evaluation of transfer of ICS training to military operations.

The research program has never focused on simple VE-based simulation of soldier tasks or missions, but on the fundamental skills that provide the foundation for many soldier activities and tasks. The research plan for this program is represented in the hierarchical scheme shown in

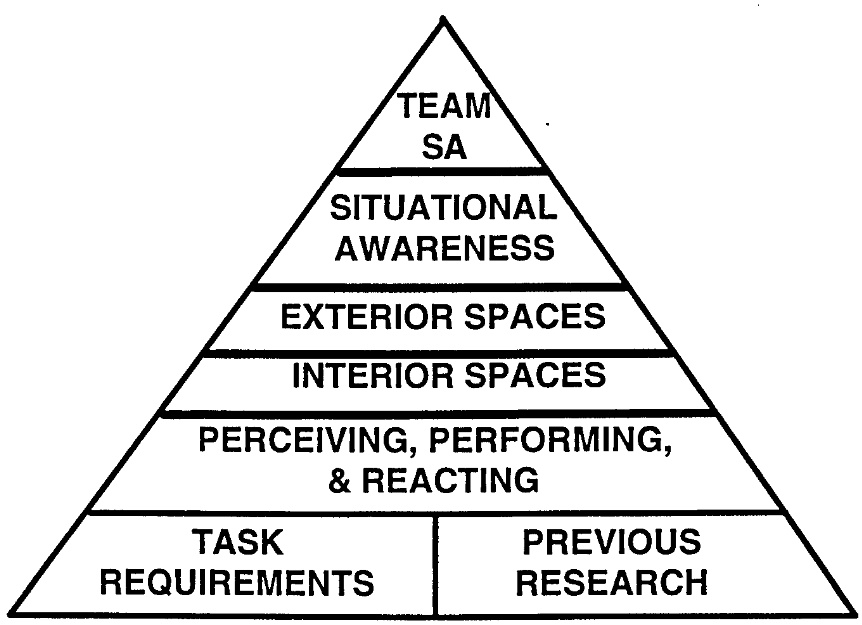

Figure 1. The VE research pyramid.

Figure 1, the VE Research Pyramid (Knerr et al., 1994). The foundation of the pyramid was laid on the identification of the military task and activity requirements for dismounted soldier training using VE technology (Jacobs et al., 1994; Levinson & Pew, 1993). The lower levels encompass research in psychophysical capabilities required for fundamental soldier activities in VE; the capability to perform psychomotor acts based on those activities in VE; and comfort, convenience, and side effects in the VE. The middle levels of the research pyramid address the fundamental soldier skills of spatial knowledge acquisition, terrain appreciation, and route planning in VE. The topmost levels of the pyramid focus on experiments investigating the training of SA in VE at the individual and team levels. It is this level of VE training which is the focus of this report. SA is the ability of an expert in a field to formulate an accurate, coherent overall picture or story of an ongoing, complex, high stakes situation and as well project scenarios of that situation into the future.

The purpose of this report is to provide an assessment of the capability of current VE technology to provide team SA training. This assessment will be conducted in the context of small dismounted units, to include fire teams, squads, and platoons. The term "small unit leader" will be used as a general term to include fire team, squad, and platoon leaders.

Since there is no direct evidence regarding the capability of VE to provide SA training, the approach taken to this report must be analytical. It will begin by reviewing the trends which appear to be changing the activities of small unit leaders. It will then review the concepts and research in several areas related to team SA training: SA concepts, cognitive processes in SA, naturalistic decision making, and team training. These reviews will form the basis for a list of suggested requirements for team SA training. A brief description of VE technology will then be presented, with emphasis on its capabilities and limitations for training dismounted units and team SA. Training strategy considerations and potential instructional features for use in team SA training will then be discussed. Finally, research needs and a strategy for conducting that research will be presented.

Dismounted Infantry Training Requirements

Current training resources are challenged to provide adequate training for preparing small unit leaders of dismounted infantry (DI) for both combined arms operations and contingency operations. The need to provide appropriate training for these leaders will become even greater in the future as their responsibilities are greatly increased. This section describes current performance shortfalls and an expected increase in the responsibilities of small unit leaders.

CALL has reported deficiencies in the employment of DI during offensive operations during FY 95 and the first half of FY 96 at the National Training Center (NTC) (CALL, 1996). A result of these deficiencies is that the dismounted element is either committed without support against superior enemy forces and destroyed, or becomes largely irrelevant and unable to influence the fight. One highly relevant problem is that when called upon to dismount, dismounted leaders and soldiers are too often unprepared to accomplish their mission: they leave essential equipment (radios, anti-tank weapons, etc.) behind; they are unfamiliar with the tactical

situation; and they are unsure of what they are to accomplish. These problems are symptoms of a lack of SA.

The importance of small unit operations is expected to greatly increase. The U.S. Marine Corps "Sea Dragon" project presents a concept of the role the small unit leader will play in combat in the near future. Small, widely dispersed units will call indirect fire on large enemy units. In this concept, a central command passes an "intent" to each team, which then independently carries out the mission in accordance with the local situation ("Sea Dragon", 1996). Thus, in the near future, both the responsibility of the local team leader and the criticality of successful performance by each small team will be greatly increased. The Sea Dragon concept places maximum emphasis on improved simulation-based training.

Looking further ahead, the Small Team Portal-21 (STP-21) project envisions small teams with the ability to call indirect or air-delivered fires with a combination of precision and firepower to fulfill missions assigned to a current brigade-size force (Salter, Knerr, Lampton, Fober, and Dressel, 1996). TRADOC's Army After Next, which focuses on warfare between the years 2010 and 2025, envisions squad leaders making decisions that could have strategic national importance (Naylor, 1996).

These changes are likely to push the need for SA training to increasingly lower echelons of command. Force XXI appears to be shifting "...both information and responsibility down the chain of command" (Naylor, 1996, citing MG Scales). Soldiers will become more capable of either autonomous or small group action. Therefore, soldiers will also need to be more adaptive. When the information and responsibility shift to lower echelons does occur with more sophisticated equipment, SA will become a more important factor at these traditionally lower levels of command. More sophisticated equipment will permit lower echelons to have more information about the tactical situation, command of more firepower, and greater physical separation from their parent unit. This should also lead to increased independence of action and decision making responsibility. This in turn should require greater awareness of the tactical situation.

Conceptual Approaches to Situational Awareness

The most cited definition and model of SA in the psychological research literature has been proposed by Endsley (1995a; 1995b). She defines SA as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (1990, as cited in Garland, Phillips, Tilden, & Wise, 1991). In keeping with this definition, she proposes three levels of SA. In Level I SA, the individual perceives the elements in the environment. However, this act encompasses more than simply observing some object. One must grasp their status, attributes, and dynamics (Endsley, 1995a). Therefore, a small unit leader must know what friendly and enemy forces are in an area, their capabilities, and the dynamics and relationships of these forces. In a similar way, the leader will be taking note of the terrain and weather conditions.

Level II SA involves comprehending the current situation in light of one's goals. This comprehension is based on the synthesis of the disjointed information of Level I SA. In other words, the significance of the forces, their capabilities, status, dynamics, and relationships to one another are integrated into the current leader objectives. For example, the leader integrates his observations of enemy forces and the terrain in light of his unit mission. This Level II organization, therefore, is an integration of all significant environmental elements.

Level III SA is the projection of future status. Building on the first two levels of SA, the individual now attempts to project the actions and alignments of the elements of the situation in the future. For example, the leader will not only be thinking where each of his and the enemy forces are, but will be anticipating, based on constructed models, where the enemy forces may move, and where he will need to deploy his forces in the future. Thus, SA focuses on one's understanding of the situation, and views the individual as an active information seeker acting pro-actively rather than reactively.

U.S. Army publications frequently use the term SA without defining it, and those that do define it do not do so consistently. FM 100-6, Information Operations (Department of the Army, 1996), and FM 100-7, Decisive Force: The Army in Theater Operations (Department of the Army, 1995) use the term SA to refer to shared (across units) information about the locations of enemy and friendly units on the battlefield. This corresponds to Endsley's Level I. FM 100-23, Peace Operations, (Department of the Army, 1994b) and FM 100-5, Operations (Department of the Army, 1994a) also include the perception and anticipation of changes in the environment as part of SA. This corresponds to Endsley's Level III.

As a general starting point, Endsley's model is quite good and thorough. Unfortunately, Endsley (1995a) describes SA as a state, despite depicting it as a dynamic, active process. She calls the process of attaining SA situation assessment, and thus, that becomes the dynamic component. For example, she notes that SA is limited by attention, working memory, information access, information processing, comprehension, and response execution (1995b). As such, she sees processes like decision making as integral to, but separate from SA. Although Endsley's model appears to be a levels of processing framework, so that SA would be the product of the collection and integration of information from the various levels of SA and its attendant processes, she sees decision making and information processing as separate from SA. "I feel very strongly that we cannot allow our use of the term [SA] to include decision making and performance. These are clearly different stages which have different factors impacting them and which indicate wholly different approaches in dealing with them" (Endsley, 1994, p. 316). However, decision making is not as independent of SA as she seems to suggest. Depending on his ultimate goal, the individual will pay attention to different information and organize that information differently. Endsley's Level II SA even suggests this -- that the individual comes to understand the information he is perceiving in light of his goals. Similarly, the mere perception of the environment (Level I SA) will be influenced by the ultimate goals and decisions of the individual. Therefore, the strictly linear nature of Endsley's model is suspect.

More importantly, Level II and Level III SA actually serve as the guiding points for Level I. This is akin to what Adams, Tenney, and Pew (1995) have pointed out about SA's relationship to

Neisser's (1976) schema-based perception-action cycle. In this cycle of knowledge acquisition, the individual perceives information in the environment which alters his knowledge and understanding. This knowledge, in turn, directs the activities of the individual and his interaction in the environment. Additional information is gathered, and the cycle continues. According to Smith and Hancock (1995), SA is at the core of this cycle. It links together and makes coherent the phases and information of the perception-action cycle.

Alternatively, Pew (1995) approaches the concept of SA by first defining what is meant by "situation" and "awareness." For Pew, a situation is a set of conditions or states within an environment which has unique information and knowledge states as well as response options. Awareness is the information and knowledge state of the individual(s) within that situation. The information and knowledge states allow those involved not only to support current activities, but also anticipate future events. What Pew finds important are the transitions between situations. His approach focuses on the more active and dynamic nature of working through a situation, and suggests the possibility that two processes are going on in SA. First, the individual is constantly gathering information, organizing it in light of his goals, and anticipating future events to some extent, because a goal-based decision will eventually be required. Second, at critical moments when something in the environment changes, the individual must formulate a new set of understandings of the current situation and projections of future states based on these changed conditions. Any misperceptions or misinformation the individual possesses may produce drastic detrimental performance and decision-making consequences.

Other researchers have questioned the value of the SA concept. Federico (1995) and Charness (1995) feel that the research and theory on SA is essentially the same as the research and theory on the differences between expert and novice decision makers. Charness notes that SA seems to be understood as a "default value" in performance. If someone performs poorly, it is because he did not have good SA. On the other hand, if he performs well, he had good SA. Thus, SA is circularly defined, and therefore non-descriptive. According to Charness, SA describes what is essentially expert performance. However, according to Andre (1995), performance measures are often the main dependent variables in SA experiments. Therefore, if SA is merely good performance or expert decision making, the concept provides little additional value.

Such a pessimistic view of the concept may not be warranted, however. Researchers have noticed a valuable process that they are trying to understand. SA is attempting to answer the following questions: What is a person who performs well attuned to, and how is he organizing information? Integral to this process are the decisions the individual will have to make in light of given goals. Although the individual needs to be attuned to detailed information in the environment, that information must always be perceived in terms of current goals. The individual will use past experience, the history of that particular situation, over-learned scripts, subtle cues of which he may be consciously unaware, etc., to formulate plans as well as to interpret current and future situations. None of these processes are value-independent of the current goal, but come together to form a Gestalt or story (Klein, 1995) of the current situation. This Gestalt forms the basis of multiple future projections of the situation and its composite elements. These processes are especially important at critical times when environmental/

situational factors change so that the individual must reformulate new or alternate plans and goals. Therefore, what we know of expert decision making is vitally important, but does not necessarily cover the complex and dynamic environments in which SA seems so vital, e.g., combat situations as opposed to a chess game.

One of the main presuppositions of Endsley's model, which is implicit in many models of SA, is that one needs to begin with Level I awareness (with the perception of the elements of the environment). Level I SA issues are much more easily accessible by current scientific methodologies than Level II or Level III. However, as noted above, this may not be an appropriate starting point. One must not only understand information in light of current goals, but also be able to anticipate future actions, consequences, and scenarios. Because a holistic understanding of a situation is the hallmark of good SA, it may be more fruitful to take Level III SA as the starting point for investigation and training. What is happening in the present and has happened in the past may come together more effectively from a more encompassing vantage point. For example, knowing that the enemy will try to take a certain piece of terrain already entails a story to which the leader is attuned. This knowledge helps him form hypotheses and interpret current actions (the enemy is doing X to accomplish Y), and guides him to look for specific clues in the current situation relevant to that story. As such, the individual is not left to construct a story and interpretation from the disjointed objects in the environment. On the other hand, if one's initial Level III understandings and story are incorrect, one's anticipations and perceptions will also likely be incorrect. The error is exacerbated as expectations color perception through selective sampling of the environment. Poor performance, including failure to successfully accomplish the mission, injury, and loss of life are among the potential outcomes. Therefore, SA must also focus on critical thinking (e.g., looking for errors or incorrect hypotheses).

Researchers have focused on a linear model of SA (one that progresses sequentially from Level I to Level III). At the very least, however, the development of SA is an iterative process. At each new re-examination of the various levels, the individual is putting together information, forming hypotheses, and discarding hypotheses. For instance, Rasmussen (1986) diagrams the information flow map of formal, systematic strategies in a diagnostic task. In this diagram, he shows apparently disjunctive jumps between strategies. In these jumps, the individual is forming a hypothesis, finding something in the environment which might suggest something else, recalling previous experiences which brings yet another model of understanding to mind, etc. This continues the cycle of updating his understanding of what is happening as described above in the SA process as a perception-action cycle. Rasmussen does not depict a logically straightforward linear process, but does follow how expert diagnosticians are actually thinking through the problem.

Cognitive Processes in Situational Awareness

What is the best approach to develop SA at the individual or team level? How can the individual develop and maintain a holistic understanding of the situation and its interrelated parts?

The individual must implicitly or explicitly have a series of questions in mind about the situation that help build the SA understanding. These questions are context specific, and vary in level of abstraction (see Shrestha. Prince, Baker, & Salas, 1995, for further review). Where are the players in the scene located? What is their location and spatial relation to one another? What are the potential threats and the enemy objectives? Who is in command of the enemy and friendly units? Similarly, as indicated in the general discussion of SA, one must monitor mission objectives, orientation in space, environmental conditions, external support, equipment status, and the capabilities and status of personnel. One must also construct a timeline and story of the events of the mission. Finally one must also focus on what he can control within the situation. What can one and one's troops do, control, compensate for, and how can they manage to do so? Is action required, and if so, what are those actions? Obviously, any actions taken must be monitored and integrated into one's developing understanding of the situation.

Some of the answers to the above questions are obviously quite specific, such as the spatial location of all forces involved. However, inherent in the answers is the building of a more holistic understanding of the situation. Answers may be context-specific, but the "process of answering" may generalize. For example, in taking note of the locations and spatial relations between forces and objects, the individual is noting more than the coordinates at which an entity is located. Rather, these objects are already being put together in a meaningful relational scenario. Similarly, in keeping the timeline of events in mind, events in the past help inform and construct one's understanding of the present story and anticipate future actions. At the other extreme, one must keep in mind overall mission goals, e.g., can this mission still be accomplished? Does the battle plan need to be altered? Although research efforts may concentrate on one level of abstraction or the other, in the real-world focusing only on one level can be devastating. Good SA requires simultaneous monitoring of multiple levels of abstraction.

Looking out for errors and conflicting information is equally important to good SA, and this will be difficult to train because of confirmation bias in hypothesis testing. Wason (1960) has noted that in decision making people only look for information that confirms their current hypothesis, disregarding information that may disconfirm it. Therefore, Schwartz (as cited in Shrestha, Prince, Baker, & Salas, 1995) suggests that people must be trained to recognize signs of team errors, such as not finding targets in the expected location, or deviations from the appropriate procedures for the situation. Similarly, feeling confused, not resolving conflicts or misunderstandings, having incomplete information, and withholding information and suggestions signify potential problems with SA.

As already indicated, decision making is an integral part of formulating stories, devising plans, and looking for errors. The current model of decision making in mainstream cognitive psychology is based upon a logico-deductive model of thought processes (Campbell, 1989).

However, there is substantial evidence that real-world decisions do not follow this model. Therefore, some other processes must be at work. Klein (Klein, 1995; Klein & Wolf, 1995) emphasizes the role of past experience in decision making. For example, the fighter pilot is not simply calling upon procedural rules (see Anderson, 1993) such as "if there is an enemy plane within x meters, do y." Rather, he is calling upon past experience (what enemy planes have done in past similar situations) to determine not only what that plane might be doing at the moment, but also what it might do in the future. Similarly, Klein notes that as one perceives, collects and processes data, one is integrating them into plausible stories, and it is upon the basis of these stories, not logical or deductive thinking, that one comes to a decision.

New research from physiology on how the brain works produces a different metaphor and conceptualization of human decision making: the connectionist or neural net theory. According to this viewpoint, information is not stored in the brain in a physically locatable position. Rather knowledge of something is stored as a particular constellation of weighted connections between neurons of the brain. As a consequence, the brain works as a pattern detection system, not as logico-deductive one. Similarly, the SA literature points to the possibility that people do not reason deductively, but rely on past experience and the sense and meanings they have taken from them as major guides in decision making. Rasmussen's (1986) model as taken up by Kass, Herschler, and Companion (1991), indicates that people often do work as pattern detectors, rather than deductive thinkers. They trained subjects to recognize patterns in a minimal cue environment. Subjects trained in this way were better able to detect patterns in a more complex stimulus environment than those who had not been so trained.

Thus Orasanu's (1995) suggestion that individuals undertake numerous training or practice experiences in a variety of contexts and scenarios can be understood as a way for the individual to develop his own network of connections for quick decision making. The greater one's experience, the more connections one will have formed. Therefore, the quicker and more accurate one's decisions will be, because one has more information available to detect a viable pattern from less and less information--each minute piece of information will be connected to more and more possible scenarios.

A related concept in complex decision making environments is workload. Workload is generally understood in terms of attention and attentional resources. It is hypothesized that people have a limited pool of attentional resources. The more resources spent looking for the enemy, for example, the fewer resources available to process this information and come to a battle decision. However, not all activities require attentional resources. When someone has reached the level of automaticity or skill-based behavior (Rasmussen, 1986; Anderson, 1993; Ashcraft, 1989), few attentional resources are used up in completing the task. This is particularly the case with expert performance. Novices, on the other hand, have to devote considerable attention to that same task.

Obviously, how much of one's resources are being used has major implications for task performance and training procedures. If an individual can be trained to more automatically process environmental and task information, resources will be freed up to search for further information and come to a decision during a crisis situation. The more consistent the situation

the more resources will be available during a crisis. However, the more heuristics, situation models, mental models, and pattern-recognition templates the individual has acquired, the more quickly the individual can adapt. As such the individual will use fewer attentional resources during a crisis situation, because more cognitive tools and resources are available. The expert or skill-based individual processing or performing a given task will exhibit and experience fewer workload decrements. Experts quickly perceive the stimuli that identify the correct model for the situation (Klein, 1993) and have more complex and accurate models than novices. Therefore, training approaches must focus on bringing the individual up to expert level information processing and interpretation in complex environments.

From a cognitive perspective, in order to train SA, the individual must be trained to construct a coherent story in which questions about mission objectives, spatial orientation, troop positioning and movement, what can and cannot be controlled, what actions are possible, etc., are posed and answered. The individual should be trained to look for and anticipate errors and gaps in this story. In addition, pattern detection, e.g., troop placement and movement, should be trained. Finally, practice with a variety of scenarios must be undertaken to build up scripts and rapid cue identification to reduce workload and finely tune SA.

Environmental Considerations: Naturalistic Decision Making

The context in which SA is generally accepted to occur is as important a consideration for training as the cognitive factors involved. Although one could speak of SA in terms of a chess match, for example, it is not the context which most appropriately depicts SA. A chess game is much more like the typical laboratory-based context in which basic decision making, attention, etc., are studied. Under such circumstances, information given to the subject is well controlled and straightforward. However, in the "real-world" life is much more complex and ambiguous. The problem space and the decisions to be made are usually not as clearly defined and goals and information are often contradictory. Research in the related area of Naturalistic Decision Making (NDM) begins to address the contextual concerns in decision making in complex, dynamic situations.

NDM, as the title implies, takes as its starting point decisions the individual makes in his everyday life, rather than in the contrived situations used in laboratory studies. NDM theory looks at how people go about making decisions in the real world. It proposes that a great deal of decision theory research up to now has been normative work, missing critical aspects of everyday decision making (see Endsley, Klein, Woods, Smith, & Selcon, 1995). According to Orasanu and Connolley (1993) NDM context characteristics include:

1) ill-structured problems
2) uncertain, dynamic environments
3) shifting, ill-defined, or competing goals
4) action-feedback loops
5) time stress
6) high stakes

7) multiple players
8) organizational goals and norms.

Such circumstances cannot easily be re-created in a laboratory experiment. However, the ability of VE to be immersive, create complex environments and scenarios with which one can dynamically interact make it an ideal place to study and train SA skills. What is important is that the individual be able to practice using or developing expert decision making in naturalistic contexts. It is for this reason that Orasanu (1995) suggests that the individual must be given a variety of decision-making scenarios, so that he can develop SA strategies and responses. In other words, the training environments must be just as complex as the real-world tasks to which they are geared, or the very assumptions and premises of NDM (and SA) will be violated. Training scenarios should include the environmental factors outlined above.

Military Teams and Situational Awareness

One of the most important issues in the area of team SA training is the allocation of training resources to team members. Who is to be trained? Is it the team leader, selected key members of the team, or all team members? Are they to be trained independently, or as a unit? Further discussion of teams and team training is required before this issue can be pursued.

Teams are different from groups, mobs, or collections of individuals. Teams are groups of individuals with one or more common goals that require coordinated, interdependent, and adaptive performance by those individuals (Salas, Dickinson, Converse, and Tannenbaum, 1992). Duffy (1993) elaborates this definition by adding that members have specialized knowledge, accountable membership, usually work in unpredictable environments, and process information for variable lengths of time. This broad definition implies that many widely ranging factors affect team performance. A plethora of factors can be examined in team behavior and performance: personality factors; the structure of the group; the time the group has been together; the placement of the group within a larger organization; ability to work together; satisfaction of member needs; acceptability of outcomes; level of effort of members; individual skill and knowledge levels; task appropriateness; resource allocation; and team development (Hackman, 1993; Forsythe, 1990; Gersick, 1989; Morgan, Glickman, Woodard, Blaiwes, & Salas, 1986). What is most important for team SA are those team factors which increase the ability of the team to assess the current situation and anticipate future contingencies. These processes must occur within the team to increase team effectiveness as well as within the larger context of the specified mission.

Team effectiveness can be conceived as an input-throughput-output model (Urban, Bowers, Cannon-Bowers, & Salas, 1995). Input variables are the characteristics and resources with which the team must deal. These include individual characteristics (personality factors, attitudes, skills, and abilities), team characteristics (the team's collective skills, abilities, and personality), task characteristics (task features which confront the individual such as individual workload), and work characteristics (features which confront the team as a whole, e.g., organizational structure, team workload, and environment). Throughput factors are the processes of team coordination,

communications, and decision making that transform the inputs into the outputs, i.e., performance of the team and its members. Aviation research indicates that high error cockpit crews have problems with communications, crew interaction, and integration of information. Often they do not communicate information or are interrupted by others, and so do not fully attend to their task and information obligations. Similarly, information that is available is either not communicated or not acted upon (see Wiener & Nagel, 1988). Communication provides the basis upon which team members are able to coordinate tasks for successful completion (Achille, Schulze & Schmidt-Nielsen, 1995). Team coordination itself is a vital process. "Process loss" as a result of poor coordination has been a documented phenomenon in the group performance literature for many years (see Forsyth, 1990). Stout, Salas, and Carson (1994) found that when individual skill was covaried out of mission performance "overall coordination of the team accounted for significant and unique variance in team performance" (p. 189).

All teams are characterized by interdependency of their members and have some form of structure, even if minimal (Salas, Dickinson, Converse, & Tannenbaum, 1992). These characteristics produce at least a two-dimensional model for describing teams. One dimension is the degree of interdependence required to accomplish one or more of the tasks. The other factor is the structure of the team. Because military teams are inherently highly structured, the most important dimension for training purposes is interdependence: team members acting dynamically with one another in exchanging information, coordinating activities, and adjusting to task demands and changes (Salas, Dickinson, Converse & Tannenbaum, 1992).

In addition to these team process variables, there are cognitive factors that are equally important, especially when discussing SA. Shared mental models of the situation, problems, equipment, team member tasks, team member needs, and team member actions are crucial to good team performance. These shared mental models, sometimes called transactive memory systems (see Liang, Moreland, & Argote, 1995), also include an understanding among group members of who knows what. The more accurate these mental models are and the more they are shared by team members the better the interdependent coordination and communication activities will be (Minionis, Zaccaro, & Perez, 1995). For example, the more one team member understands another team member's information needs, the more he will be able to anticipate these needs and supply information on time or even in advance. Further, because the team is comprised of two or more people, each person can individually access and supply information. Thus, the team becomes an information pool for the present context as well as future scenarios (Salas, Dickinson, Converse & Tannenbaum, 1992). Therefore, team SA can be understood as the "sharing of a common perspective between two or more individuals regarding current environmental events, their meaning and projected future status" (Wellens, 1993, p. 272). The greater the team SA, the more coordinated it will be and the better it will perform. Although mental models need to be shared among members, they cannot be totally overlapping, or the advantage of member specialization, pooling of resources, and distribution of monitoring tasks will be lost.

Team Training and Situational Awareness

Teams are composed of individuals, and this reality carries with it two implications. First, the patterns of communication and ability of the individuals to cooperate with one another affect the team as a whole. For example, Prince, Salas, Bowers, and Jentsch (1995) have found that more successful teams spend a significantly greater amount of time communicating with one another and discussing alternative actions than unsuccessful teams. This implies that without adequate individual communication skills, the individual task performance skills of the team are limited. Communication must be based in and support a shared mental model of the situation state and tasks, so that team members are able to work together rather than operating at cross purposes. Second, the skills of the individual influence team performance. One of the most salient team members is the team leader. This person must coordinate and guide the unit's efforts, allocate resources, coordinate and communicate with other teams, etc. The leader's style, abilities, and decision making take on added importance relative to other team members. This reinforces the need to concentrate on the SA and decision-making abilities of the leader in military situations.

Salas and his colleagues have designed several methods specifically to train teams, rather than individuals within a team (Salas, Cannon-Bowers & Johnston, in press; Urban, Bowers, Monday, & Morgan, 1995). Cross training tries to develop shared expectations and mental models of team member functioning. It is a straight forward approach in which each team member practices other members' jobs. This practical experience will inform the individual of what each member's responsibilities, resource needs and coordination requirements are (Salas, Cannon-Bowers & Johnston, in press; Urban, Bowers, Monday, & Morgan, 1995). As a result, when the individual returns to his role, he will have a better understanding of what other members require at various stages of task completion. He will better be able to anticipate their needs and actions, thus increasing team coordination, decision making, and performance. Cross-training should also provide a larger framework in which a team member can understand his or her own function as an integral part of the whole team (Urban, Bowers, Monday, & Morgan, 1995). This method of training is particularly useful for teams in which there is likely to be a high degree of member turnover. When teams are together for an extended period of time, members begin to learn the information requirements and roles of one another as they work together. However, in high turnover teams, the members do not have a chance to become acquainted with these coordination factors. Cross training helps to alleviate these lack of familiarity effects. Such a system has already been developed for Navy shipboard combat information center (CIC) team members. Individuals learn about the task and/or team knowledge domains, observe a scenario, participate in a scenario-based simulation, and finally, work in a different position. A 10% improvement in knowledge about appropriate team communications was found using this system (Duncan, Cannon-Bowers, Johnston, & Salas, 1994, as reported in Salas, Cannon-Bowers & Johnston, in press).

Another approach to team training is to focus directly on team coordination processes rather than individual skills and mental models within the team. This type of training is particularly important during times of stress--a key situational variable in SA--because successful teams adapt to increases in stress by changing their coordination strategies. In the Team Adaptation

and Coordination Training (TACT) approach, team members are instructed in how to identify stress reactions and shown adaptive strategies to deal with workload increases. In addition, the team leader is instructed to periodically update all team members on his assessment of the situation. These skills are practiced in training scenarios before experimental test scenarios begin. As a result of this training, communication patterns within the team changed. Specifically, there was a "...stronger push of information to the team leader, and more anticipatory behavior" (Salas, Cannon-Bowers & Johnston, in press).

In general, any team training system, particularly a team SA training system, must focus on developing shared mental models of the task including how to accomplish the task, team member roles, and team member information needs. Similarly, they must also advance team coordination and communication skills, especially the latter as communication forms the basis of coordination. Therefore, in terms of SA, patterns of situation interpretation and anticipation must include linking patterns of interaction within the team and the environmental context with both current and future task parameters and team member needs and actions.

Requirements for Team Situational Awareness Training

The following requirements for team SA training are hypothesized from the information in the previous sections of the report. The discussion of cognitive processing indicated that:

- People should be trained to ask and answer a series of questions to develop a holistic understanding of the situation. This should include training in looking for information that conflicts with their current understanding.
- The training should include numerous experiences in a variety of contexts in order to facilitate pattern matching.
- Frequent practice should be provided to develop some skills to automaticity and thereby reduce workload.

The discussion of NDM suggested that the training context should be as complex as the real-world situations to which the training is to be applied. Specifically, the training context should include:

- Ill-structured problems
- Uncertain, dynamic environments
- Shifting, ill-defined, or competing goals
- Action-feedback loops
- Time stress
- High stakes
- Multiple players
- Organizational goals and norms.

For training purposes, it may not be necessary for all of these elements to be present all of the time. It may be desirable to initiate training in a relatively simple context, and increase the complexity as trainee proficiency improves.

The discussion of team training indicated that:

- Team members need to develop shared mental models of the situation, tasks, and roles. Cross-training is one way for team members to develop an understanding of each other's tasks and roles.
- Coordination and communication skills should be trained.

Virtual Environments

A VE system has been defined by Stuart (1996) as

> a human-computer interface that provides interactive multi-sensory 3-D synthetic environments; it uses position tracking and real-time update of visual, auditory, and other displays (e.g., tactile) in response to the user's motions to give the user the sense if being "in" the environment (p. xx).

Wickens and Baker (1995), on the other hand describe Virtual Reality, a term frequently used interchangeably with VE, as a concept which can be broken down into five features, each of which can be present to a greater or lesser extent:

- three-dimensional viewing;
- dynamic display;
- closed loop interaction;
- ego-referenced frame of reference (the VE is displayed from the point of view of the user's head); and
- interaction through multiple sensory modalities.

VE offers a potentially effective supplement to field exercises for training and testing novice leaders and teams. VE simulation would allow multiple players, simulated terrain, and computer generated forces to mimic the behavior of soldiers, squads, and enemy forces. In addition, VE training platforms would support a wide range of variations in the situation, so novices can practice their command skills in a number of scenarios and environmental conditions. This variation and rapid repetition supports practice-based learning by the leader, allowing the development of detailed scripts, improved attention to cues, and appropriate communication and leadership skills, which are vital for team SA. This training could be provided to individuals (who participate in scenarios with simulated superiors and followers, and against a simulated enemy) or to entire units (who would train simultaneously using networked simulators).

VE has a number of potential advantages for team SA training. The first is the capability to place an individual in a number of varied situations and provide repeated experiences rapidly.

The same or similar scenarios could be run: in daylight or at night; in the jungle, desert, or mountains; against elite troops or poorly trained militia; and with varied rules of engagement. This varied experience could be provided at a single physical location, without requiring extended transportation of soldiers and equipment. The second advantage is that VE training is potentially less costly than live simulation alternatives. This is particularly true if the training is focused on the leader, rather than the entire unit. The use of computer models to represent the other soldiers (role players) eliminates the inefficient use of an entire unit to train one person, its leader. It also reduces the need for ranges and exercises. Third, VE training eliminates many of the safety risks associated with field exercises. While simulator sickness presents some potential risk (Kolasinski, 1995), this is minor compared to the risk of injury in live exercises. Fourth, VE training is more amenable to the use of certain types of instructional features and strategies than are live exercises. This will be discussed in more detail in a later section. Finally, the trainee can be visually and auditorially immersed in the simulated environment. VE can provide a compelling sense of actually being in a simulated environment, and can provide sufficient realism to train routes through complex buildings and the identification of specific terrain features (Knerr, Goldberg, Lampton, Singer, and Witmer, 1996).

Virtual Environment Capabilities and Limitations

The major drawback to the use of VE is its relative technological immaturity. The technology elements necessary to represent individual soldiers in VE include: visual and auditory display systems, position and orientation tracking, systems for representing self motion, techniques for representing humans, and speech recognition. The general state-of-the-art in these areas has been reviewed by Durlach, Pew, Aviles, DiZio, & Zeltzer (1992), and Durlach and Mavor (1995). Levison and Pew (1993) and Jacobs et al. (1994) also reviewed the state-of-the-art from the perspective of training and mission rehearsal for dismounted soldiers. Levison and Pew concluded that the technology expected to be available in the near term (less than three years) had the potential to provide training benefits. Jacobs et al. (1994) analyzed 252 individual activities required by dismounted soldier ARTEP tasks and found that 44 could be performed in VE with the then existing technology or modifications of it. It was expected that an additional 40 could be supported by technology expected to be available in the near term. However, this referred to the capability of technology to provide complete performance of all aspects of the activity. The use of simplified or substitute components of the activity (i.e., selecting "Emplace mine here" from menu rather than physically emplacing a virtual mine) was not considered. Such substitutes would allow training benefits to be achieved now.

This section will not provide a detailed review of the capabilities and limitation of VE technology. Several recent sources (Stuart, 1996; Youngblut et al., 1996) have already covered this area thoroughly. It will identify significant capabilities and limitations of VE technology as they are related to the training of dismounted teams and team leaders.

<u>Visual display systems</u>. There are a variety of display devices which can be used to provide an immersive, ego-centered view of a computer-generated environment. Of primary interest are low cost (less than $8,000), Liquid Crystal Diode (LCD)-based, light weight head mounted displays (HMD). These are usually equipped with trackers so that the image viewed is linked to

head movements. These systems are fully capable of providing binocular vision and most monocular distance cues. They also provide freedom of movement, although within a limited area. However, their low visual resolution limits the amount of visual detail that can be presented, and the distance at which objects can be seen. Thus in a typical LCD-based HMD (see, for example, Rinalducci, Cinq-Mars, Mapes, & Higgins, 1996) a standing 6 ft tall dismounted enemy figure would be less than one pixel in height at a simulated distance greater than 372 meters, and could be recognized as a human figure only at a considerably closer distance. In order to achieve even this resolution, the field of view must be limited.

CRT-based systems can provide greater resolution, but cost and weigh more. CRT-based systems are frequently mounted on a counter-balanced boom, which limits the movements of the viewer.

Auditory display systems. Auditory display systems can be used in VE to provide the speech of simulated participants and environmental sounds. Speech can be either actual speech provided in real time by a trainer or role player, prerecorded sentences or phrases, or synthesized speech. The last approach provides the greatest flexibility. However, Stuart (1996) reports that all speech synthesizers have a mechanical sound quality and are less intelligible and comprehensible than natural human speech.

Environmental sounds can be either directional or non-directional. Non-directional digitized sounds, such as explosions and engine noise, can easily provide task-related cues and the noise to make communication more difficult. Providing sounds which provide accurate auditory localization cues (three-dimensional cues regarding direction, distance, and changes in both) is considerably more difficult. While systems which can provide these cues are available, considerable effort is required to accommodate individual differences (Stuart, 1996), and specialized technicians are also required to apply the technology (Youngblut et al., 1996).

Position and orientation tracking. Position and orientation trackers perform three functions for leader training: linking the contents of the visual display to the user's viewing direction; tracking weapon orientation; and tracking limb position in order to represent the user to other individuals in the VE, and to interpret hand and arm signals. A variety of position and orientation trackers, which use several different technologies, are commercially available. According to Youngblut et al., "...low-latency, high accuracy systems for head tracking in [an] unprepared, possibly noisy environment do not exist." (1996, p.76). The major constraint for tracking is that the object to be tracked (user's head, limbs, or weapon) must remain in a fairly constrained area. Trackers are also subject to interference, depending on the particular technology employed. For example, electromagnetic trackers are subject to interference from ferrous objects and electrical fields in the environment, while optical trackers are subject to occlusion by intervening objects. The use of tracking systems for recognition of large gestures (hand and arm signals) has not been evaluated.

Self motion. Perhaps the most common means of navigating in VE is through the use of simple control devices, such as a joystick, spaceball, or "flying mouse" that give the user control over speed and direction but do not attempt to replicate the muscle movements or physical

sensations of walking, running, or crawling. Less complicated, but somewhat more realistic, is the use of treadmills (e.g., Singer, Allen, McDonald, and Gildea, in press) or other exercise equipment. At the most realistic end of the spectrum are a few experimental devices which attempt to produce a realistic sensation of walking or running. The SARCOS Research Corporation's Treadport tethers the user in the center of a large treadmill, and permits walking, running, crawling and sitting (Youngblut et al., 1996). The Omni-directional Treadmill (Virtual Space Devices, 1996) uses a unique design to permit the user to walk or run in any direction while remaining centered on a platform. Both are used with multi-sided rear-projection visual systems. The Dismounted Soldier System (DSS) uses the standing body position of the individual, relative to a zero point, to indicate speed and direction of movement, with speed increasing with the distance from the zero point (Klasky, Anschuetz, Molnar, and Jones, 1996). The use of these systems has not been evaluated, however, and they currently exist only as prototypes.

Representation of humans. Virtual representations of human figures are required in order to represent both "live" humans and computer controlled humans in the VE. These human figures are needed to represent friendly forces (subordinates, unit members, and superiors), enemy units, and, when necessary, individuals of neutral or indeterminate status. There are two types of concerns with the representation of humans. The first is that the figures must be able to perform a set of actions (running, crawling, entering a building, pointing a weapon at an object, etc.) in such a fashion that they are recognizable to the viewer. The second is that computer controlled figures, both individually and collectively, must demonstrate basic competence in the selection of those actions (such as falling prone or running when fired upon, and moving without colliding with a wall or other figures).

There are several different techniques for representing human figures (Moshell and Cortes, 1995). In general, the different techniques represent different approaches to meeting the desire to present highly detailed, realistic, real-time motion constrained by limited processing power and network bandwidth. The most appropriate for use in combat situations are DI-Guy and JACK (Lockheed Martin, 1997). Both are being reviewed as part of the STRICOM Dismounted Warrior Network Program.

Lockheed Martin (1997) also reviewed the capabilities of available semi-automated forces (SAF) systems for controlling the behavior of the figures. These included Individual Combatant SAF (IC SAF), Modular SAF (ModSAF), Close Combat Tactical Trainer SAF (CCTT SAF), Team Tactical Engagement Trainer SAF (TTES SAF), Soldier Station SAF, and Simulation and Training Aid for the Dismounted Soldier (STRADIS). They found that the current level of technology does not permit the actions of an individual trainee immersed in a VE to be closely coupled with the behavior of a dismounted SAF unit. While the SAF unit can "see" him, avoid collisions with him, and could shoot at him if he were an enemy, the trainee cannot control their behavior by voice or gesture.

Speech Recognition. Current speech recognition systems can provide relatively high recognition accuracy with vocabularies of several hundred to one thousand words (Sticha,

Campbell, and Schwalm, 1996). Therefore, commands can be given by voice, but not by gesture. SAF, however, do not currently have the capability to respond appropriately.

In summary, VE has limitations which preclude many DI unit tasks from being performed exactly as they would in the real world. There nevertheless appears to be adequate capability to present the critical cues for task performance to the trainee and to permit the trainee to respond to those cues in a way which approximates his real-world response. By initiating research with this level of fidelity, training options can be investigated as the VE technology improves.

Training Strategies for Situational Awareness Training

In order to enhance the training effectiveness of VE, the VE system should be capable of more than immersing the trainee in a simulated environment. The VE must also permit training strategies to be implemented and instructional features to be incorporated which will provide the desired changes in trainee performance efficiently. While individual simulators and simulations have incorporated well defined training strategies, there does not appear to be a well-defined set of general strategies for device-based training, as there are for some other training media, such as computer-based training (e.g., drill and practice, tutorial). However, strategies for the use of simulations or simulators for training usually have the characteristics discussed below. They are adapted from those which formed the basis of the Reserve Component Virtual Training Program (see Burnside, 1995).

The training is performance-based. It requires the trainee to perform clearly-defined tasks to certain standards. An objective method of performance measurement is therefore required. It provides feedback to the trainee about how well those standards are met. This feedback may be immediate, or delayed, as in the case of a post exercise critique or after action review.

The training is standardized. Each student must master the same skills. It is structured. It presents the trainee with a series of situations to which they are to respond. These situations are usually organized in a progressive sequence of difficulty, going from easy to difficult (i.e., crawl, walk, run). Difficulty may be determined in a number of different ways: the complexity of the situation; the number of targets, or the amount of support provided. A means of control over the simulation, both in the initial set up and during the conduct of the exercise, is required.

The training is adaptive. The specific exercises that individuals are required to perform and the feedback that they receive is related to their previous performance.

Any VE team SA training or research programs should incorporate these documented and effective approaches to training. Instructional features provide the means to implement them effectively.

Instructional Features for Virtual Environment Team Situational Awareness Training

This section discusses the use of instructional features in training team SA. The instructional features used in a VE training system are designed to facilitate the implementation of certain training strategies, thus enhancing training effectiveness, efficiency, and transfer. A subset of the instructional features appropriate for flight training listed in Sticha et al. (1990) were chosen for their applicability to team SA training. Included are descriptions of these features, discussion of some of the underlying training strategies embedded in these instructional features, and consideration of how these features might result in improved SA for teams. The features have been organized into three groups: After Action Review (AAR) and Take Home Package (THP) Support, Interactive Instructor/Operator (I/O) Tools, and Automated I/O Support.

After Action Review and Take Home Package Support

Since the current approach to the use of simulations for combat training (at the National Training Center, and using SIMNET) relies heavily on the AAR and THP, special attention was paid to those features which support those activities.

Scenario and initial conditions control. This feature provides the I/O with the ability to configure and control simulation parameters and events. Primarily it is used to select or develop scenarios which are consistent with the overall training strategy. It can be used to implement control measures and other information to support subsequent analysis and preparation for the AAR. It may also be used to provide a variety of contexts in which the trainee can learn. Variability in training can result in positive transfer to the variety of real-world conditions which a team leader might face. The results from several studies indicate that positive transfer increases with the number of instances provided during training (see Gick and Holyoak, 1987). Therefore, leaders should practice under a range of weather and terrain conditions, facing a variety of enemy forces and configurations which present differing degrees of difficulty and opposition. Varying stimuli, during training, along certain dimensions which are known to vary in the real-world context will help the trainee to devise partially predictive rules, thus allowing for generalization to occur even though the exact situation was not previously encountered.

Record and replay. This instructional feature provides automatic recording of scenario events for analysis and review. This feature provides a means for introducing performance feedback regarding a particular segment or aspect of the simulation. For example, during the AAR, an I/O may play back a segment, providing commentary on decisions and maneuvers made, while offering instruction as to the best alternatives available. Sets of recorded performances could also be used for I/O training.

Computer-generated forces (CGF). Tactical training often requires some sort of simulation of enemy troops, and in many situations, friendly forces as well. CGF are computer models that simulate individual and unit behavior. The CGF can be either partially controlled by the I/O or completely automated. Automated adversaries can also be programmed to differ in proficiency and tactics. It becomes important to simulate the tactical style of the enemy as accurately as possible for the best transfer to the real world. However, since human behavior in operational situations is not fully predictable, a degree of variation in CGF is desirable.

Data storage, analysis, and formatting. This feature functions to store, analyze, and retrieve for use in AARs and THPs archival data on individuals, crews, and units. Systems such as the Unit Performance Assessment System (UPAS) (Meliza and Tan, 1996) and the Automated Training Analysis and Feedback System (ATAFS) (Brown, Wilkinson, Nordyke, Hawkins, Robideaux, and Huysson, 1996) provide this capability.

Automated performance measurement. The function of this feature is to assess student progress and provide information for diagnosing student performance problems. Usually this information is not used as direct feedback, but is used by the I/O to evaluate the student.

I/O station displays. The function of this feature is to provide the I/O with a display of current trainee performance during a training scenario. This information may be alphanumeric, graphic, or both. A view of the scenario as seen by the student would likely be one component. It allows the I/O to monitor performance of the individual or team, and identify significant events for discussion during the AAR. The I/O could also alter the training on the basis of his observation.

Interactive Instructor/Operator Tools

These features enable the I/O to make "on the fly" changes or adjustments while the training is under way. This may be a planned activity (e.g., freezing the scenario to show the trainee the position of all unit members as the line of departure is crossed), a response to an event that so alters the scenario that its training value is diminished (e.g., moving out in the wrong direction), or to make a teaching point.

Automated performance alerts. This feature provides for an auditory or visual alert to be presented to the student or I/O whenever student performance differs from acceptable performance standards. The purpose, according to Sticha et al. (1990), is to enhance the performance monitoring capabilities of both the student and the I/O. Automated performance alerts, therefore, may serve as the initiating cue to the I/O that intervention is required.

Freeze. This feature provides the capability to stop the simulation at any time during the training scenario. Stopping the simulation in progress can allow an I/O, through inquiry, to determine whether the trainee is attending to appropriate cues, is assessing the situation accurately, and is making correct predictions of near future outcomes. The trainee may then be instructed or coached on the relevant cues and assessments of the situation. Resuming action from the point at which it was ceased maintains the integrity of the serial order of events characteristic of a given situation. The serial integrity of certain chains of events during training allows the trainee to build a story-line from which similar real-world events may be predicted. Developing situational predictive abilities is necessary for having good SA in the battlefield.

Restart. This feature permits the I/O to return to an earlier point in the scenario and initiate the scenario again from that point. It should be especially useful for permitting the trainee to explore the consequences of different courses of action. It will also permit recovery from

disastrous outcomes without having to repeat the entire scenario. Finally, it can allow for a more difficult segment of a training scenario to be practiced several times in rapid succession.

Reposition. This feature permits the I/O to position the trainee at a point in space that is relevant to the current training objectives. Without this feature, the trainee must navigate to a specific point. Therefore, this feature may be especially economical for the training of dismounted soldiers. It also permits augmentation of the training by providing the trainee with perspectives that he would not normally have, such as a bird's eye view, or the view from a suspected or anticipated enemy position.

Demonstration. This feature provides a model of desired performance for the trainee. It is intended to utilize the benefits of observational learning in simulation (see Bandura, 1977, 1986). Demonstration of expert performance in a variety of dynamic settings can facilitate learning of situational or strategic patterns associated with various battle-related circumstances. Understanding situational patterns can lead to more accurate predictive behaviors in the real world, an ability usually associated with having good SA. According to Salas and Cannon-Bowers (1995), demonstration-based methods can also be used for team training to build shared mental models or expectations of how to coordinate and communicate. Team members can observe a demonstration of expert-level behaviors regarding the dynamics of these critical factors influencing team SA. They may also observe behaviors associated with other team roles to gain a better understanding of team member requirements. Shared mental models can allow team members to better predict information requirements and behaviors of other team members within various contexts.

Automated Instructor/Operator Support

These features relieve the burden on the I/O by automating certain training functions.

Automated adaptive training. Adaptive training, as described by Sticha et al. (1990), is an instructional approach wherein the difficulty of an exercise is tailored to the skill level of the student. Training begins at a relatively simple level and increases in difficulty dependent upon student performance.

Automated cueing and automated coaching. Automated cueing and automated coaching are related but independent features. Both require monitoring of the trainee's performance. Automated cueing supports the trainee by indicating task cues that appear to have been missed or overlooked. Automated coaching provides a coaching message, which tells the trainee to take some corrective action, or suggests a course of action. Unlike automated performance alerts, automated cueing and coaching becomes useful in reducing the mental workload of the trainee by providing procedural instructions, consequently not requiring an assessment of the situation. However such dependence on procedural instructions could result in the trainee not learning certain important cues intrinsic to the training scenario or developing SA. Therefore this type of instruction, if used, would be most beneficial in early training and should be faded as training progresses.

Computer managed instruction. This feature permits many of the training management functions to be assumed by the computer. For example, the computer can keep track of objectives that have been met and make appropriate assignments for subsequent exercises. Such a feature needs to have well established criteria for performance of various tasks. Computer managed instruction could also provide a means to implement the adaptive training feature by basing the difficulty levels of subsequent assignments on past trainee performance.

Research Issues

Who is to be Trained

There are several approaches that could be taken to train team SA: train the team leader only; train each member of the team independently; train selected key members of the team as a unit; or train the entire team as a unit. Which approach is chosen depends upon the purpose of training and the training resources available.

Training the entire team as a unit most closely meets the strict definition of team training. People are not all the same, and therefore simply not as interchangeable as machine parts. Individuals differ in skills, knowledge, personality, and style of interaction. In working together as a team, team members become accustomed to each member's strengths, weaknesses, and styles. Traditionally, this phenomenon comes under the heading of "implicit coordination" of team members that occurs over time. Training teams together, rather than individually, allows for the building of shared mental models, improving of coordination, and understanding of team members' strengths and weaknesses, which leads to greater trust in information given by one member to another as well as greater anticipation of member needs. Liang et al. (1995) found that training people within teams rather than individually resulted in fewer errors and greater team coordination, trust in member expertise, and member specialization in task components. Finally, it may improve group performance by increasing group cohesiveness through shared common experiences and greater identity with the group, (i.e., wanting the group to succeed). In addition, training in this way would allow for cross-training exercises to occur. As mentioned above, cross training helps develop shared mental models of member roles and information needs, as well as mission goals. Therefore, the possibility of training an entire team together in VE may be desirable.

On the other hand, training the entire team, as a team, is best accomplished after the individual team members have mastered their prerequisite individual skills. In addition, military teams normally suffer from personnel turnover in peacetime, even worse during combat. The team needs to be able to function acceptably no matter who is leading it. Training the leader or key team members, with the others simulated or acted by role players, is still beneficial. Finally, the computer resources required to train an entire team in VE are largely a linear function of the number of team members, since each would require their own image generator and interface unit. Training only the team leader or key team members would be far less costly. Other members of the team can then be either minimally incorporated by I/Os or more fully represented by CGF.

The proposed research approach, then, is to focus initially on using VE to train potential leaders to acquire and maintain SA. With minimal disruption to the other soldiers, a leader can achieve a more expert level of performance. In the process, the trainee will acquire experience in dealing with complex environments and the decisions, cues, scripts, etc. that are integral to good performance. These are precisely the skills which SA models indicate novices need to learn, but are not adequately learned through books or by merely aggregating previously learned skills. If this approach proves to be successful, it can be extended, either to provide individual training to each team member, or to provide training to teams. The former would be consistent with the increased complexity of the situations under which individual soldiers are expected to operate. Cross training can be introduced at any point in the process by assigning the trainee to different roles within the team.

Transfer of Situational Awareness Skills

As discussed previously, the current state-of-the-art in affordable VE poses some problems for a highly realistic implementation of dismounted unit ARTEPs or drills: low visual resolution; highly artificial self-motion; limited behaviors of computer-generated forces; and gesture recognition systems of unknown quality. VE would, therefore, in many respects be a low fidelity simulation of dismounted soldier combat. The extent to which this would preclude or limit the effectiveness of SA training is unknown. On the other hand, VE can provide complex, dynamic, immersive, multi-player environments which, at some level of fidelity, represent dismounted combat, and can in addition incorporate instructional features to enhance training effectiveness.

Research Strategy

Goals

Additional research is required to determine whether VE can be used for team SA training. The goals should be to: (a) assess the effects of the fidelity of the VE interface, the simulated environment, and the entities within it on the acquisition of SA skills; and (b) to identify factors (fidelity, instructional strategies, and instructional features) which affect the transfer of SA skills acquired in VE to the real world.

Research Environment

The simulated environment in which the research is to take place should have the following characteristics.

- The tasks should be similar to dismounted unit tasks, but sufficiently abstract to be consistent with current VE capabilities and limitations, and, at least, permit the use of non-military subjects for research.
- At least initially, only one individual should be trained at a time, with other individuals necessary for the conduct of the scenario represented by a researcher.
- Voice communication should be used between the trainee and other simulated or real participants.

- The training procedures should be consistent with those discussed under *Requirements for Team SA Training.*

References

Achille, L. B., Schulze, K. G., & Schmidt-Nielsen, A. S. (1995). An analysis of communication and the use of military terms in navy team training. Military Psychology, 7(2), 95-107.

Adams, M. J., Tenney, Y, J., and Pew, R. W. (1995). Situation awareness and the cognitive management of complex systems. Human Factors, 37(1), 85-104.

Anderson, J. R. (1993). Rules of the mind. Hillsdale, NJ: Lawrence Erlbaum.

Andre, A. D. (1995, November). Situation awareness process assessment. Paper presented at the International Conference on Experimental Analysis and Measurement of Situation Awareness, Daytona Beach, FL.

Ashcraft, M. H., (1989). Human memory and cognition. Glenview, IL: Scott Foresman.

Bandura, A. (1977). Social learning theory. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice-Hall.

Brown, B., Wilkinson, S., Nordyke, J., Hawkins, R., Robideaux, B., and Huyssoon, S. (1996). Demonstrating the concept of an automated training analysis and feedback system (ARI TR 1043). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD B215 579)

Burnside, B.L. (1995, November). Conceptual underpinnings of the Virtual Training Program (VTP) (ARI Fact Sheet). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Campbell, J. (1989). The improbable machine: What the upheavals in artificial intelligence research reveal about how the mind really works. New York: Simon & Schuster.

Center For Army Lessons Learned (1996). National Training Center trends, 1st and 2nd quarters, FY 96, section II: BOS narratives, TA.1 maneuver BOS [On-line]. Available: http://call.army.mil:1100/call/ctc_bull/1q296ntc/sec2ta1.htm#3

Charness, N. H. (1995). Expert performance and situation awareness. In D. Garland and M. Endsley (Eds.), Proceedings of the International Conference on Experimental Analysis and Measurement of Situation Awareness (pp. 35-42). Daytona Beach, FL: Embry-Riddle Aeronautical University Press.

Department of the Army. (1994a). Operations (FM 100-5). Washington, DC: Author.

Department of the Army. (1994b). Peace operations (FM 100-23). Washington, DC: Author.

Department of the Army. (1995). Decisive force: The Army in theater operations (FM 100-7). Washington, DC: Author.

Department of the Army. (1996). Information operations (FM 100-6). Washington, DC: Author.

Duffy, L. (1993). Team decision making and technology. In N. J. Castellan (Ed.), Individual and group decision making, (pp. 247-266). Hillsdale, NJ: Hove and London.

Durlach, N.I., & Mavor, A.S. (Eds.). (1995). Virtual reality: scientific and technological challenges. Washington, DC: National Academy Press.

Durlach, N.I., Pew, R.W., Aviles, W.A., DiZio, P.A., & Zeltzer, D.L. (1992). Virtual environment technology for training (VETT) (BBN Report No. 7661). Cambridge, MA: BBN, Inc.

Endsley, M. R. (1994). Situation awareness: Some reflections and comments. In R. D. Gilson, D. J. Garland, and J. M. Koonce (Eds.), Situation awareness in complex systems (pp. 315-317). Daytona Beach, FL: Embry-Riddle Aeronautical University Press.

Endsley, M. R. (1995a). Toward a theory of situation awareness in dynamic systems. Human Factors, 37(1), 32-64.

Endsley, M. R. (1995b). Theoretical underpinnings of situation awareness: A critical review. In D. Garland and M. Endsley (Eds.), Proceedings of the International Conference on Experimental Analysis and Measurement of Situation Awareness (pp. 17-24). Daytona Beach, FL: Embry-Riddle Aeronautical University Press.

Endsley, M. R., Klein, G. A., Woods, D. D., Smith, P. J., & Selcon, S. J. (1995). Future directions in cognitive engineering and naturalistic decision making. Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting (pp. 450-452). Santa Monica CA: Human Factors and Ergonomics Society.

Federico, P. A. (1995). Expert and novice recognition of similar situations. Human Factors, 37(1), 105-122.

Forsyth, D. R. (1990). Group dynamics. Pacific Grove, CA: Brooks/Cole.

Garland, D., Phillips, J., Tilden, D., & Wise, J. (1991). Theoretical underpinnings of situational awareness (Tech Report No. CAAR-15498-91-1). Daytona Beach, FL: Embry-Riddle Aeronautical University.

Gersick, C. J. G. (1989). Marking time: Predictable transitions in task groups. Academy of Management Journal, 32(2), 274-310.

Gick, M. L. & Holyoak, K. J. (1987) The cognitive basis of knowledge transfer. In S. M. Cormier, and J. D. Hagman (Eds.) Transfer of learning. (pp. 9-46). San Diego: Academic Press.

Hackman, J. R. (1993). Teams, leaders, organizations: New directions for crew-oriented flight training. In E. L. Wiener, B. G. Kanki, & R. L. Helmreich (Eds.), Cockpit resource management, pp. 47-69.

Jacobs, R. S., Crooks, W. H., Crooks, J. R., Colburn, E., Fraser, II, R. E., Gorman, P. F., Madden, J. L., Furness, III, T. A., & Tice, S. E., (1994). Training dismounted soldiers in virtual environments: Task and research requirements. (ARI TR 1011). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A286 311)

Kass, S. J., Herschler, D. A., & Companion M. A. (1991). Training situational awareness through pattern recognition in a battlefield environment. Military Psychology, 19(2), 105-112.

Klasky, R., Anschuetz, R., Molnar, J., & Jones, T. (1996, March). Dismounted Soldier System (DSS): The first virtual soldier simulator. Proceedings of the 14th Workshop on the Interoperability of Distributed Interactive Simulations. [On-line] Orlando, FL: Available: http://ftp.sc.ist.ucf.edu/STDS/workshop/14th/papers/007.doc.

Klein, G. A., (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. A. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok, (Eds.), Decision making in action: models and methods (138-147). Norwood NJ: Ablex Publishing Corp.

Klein, G. A., (1995). Studying situation awareness in the context of decision-making incidents. In D. Garland and M. Endsley (Eds.), Proceedings of the International Conference on Experimental Analysis and Measurement of Situation Awareness (pp. 177-182). Daytona Beach, FL: Embry-Riddle Aeronautical University Press.

Klein, G. A. & Wolfe (1995). Decision-Centered training. Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting (pp. 1249-1252). Santa Monica CA: Human Factors and Ergonomics Society.

Knerr, B. W., Goldberg, S., L., Lampton, D.R., Singer, M.J., & Witmer, B.G. (1996, June). Training in virtual reality: Human performance, training transfer, and side effects. In Proceedings of the 1996 IMAGE Conference. Chandler, AZ: The IMAGE Society, Inc.

Knerr, B. W., Goldberg, S. L., Lampton, D. R., Witmer, B. G., Bliss, J. P., Moshell, F. M. & Blau, B. S. (1994, Spring). Research in the use of virtual environment technology to train dismounted soldiers. Journal of Interactive Instruction Development, 6(4), 9-20.

Kolasinski, E.M. (1995). Simulator sickness in virtual environments (ARI TR 1027). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A295 861)

Levinson, W. H. & Pew, R. W. (February, 1993). Use of virtual environment training technology for individual combat simulation (ARI TR-971). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences. (AD A263 546)

Liang, W. D., Moreland, R., & Argote, L. (1995). Group versus individual training and group performance: The mediating role of transactive memory. Personality and Social Psychology Bulletin , 21(4), 384-393.

Lockheed Martin Corporation. (1997). Advanced Distributed Simulation Technology II (ADST-II): Dismounted infantry semi automated forces analysis report. [On-line] Orlando, FL: Author. Available: http://www.rciorl.com/hmts/dwncdrlab02.htm#Introduction.

Meliza, L.L. & Tan, S.C. (1996). SIMNET Unit Performance Assessment System (UPAS) version 2.5 user's guide. (ARI RP 96-05). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A318 046)

Minionis, D.P., Zaccaro, S.J., & Perez, R. (1995). Shared mental models, team coordination, and team performance. Paper presented at the 10th Annual Meeting of the Society for Industrial and Organizational Psychology, Orlando, FL.

Morgan, Glickman, Woodard, Blaiwes, & Salas, E. (November, 1986). Measurement of team behavior in a navy training environment (Tech Report 86-014). Orlando, FL: U.S. Naval Training Systems Center

Moshell, J.M., & Cortes, A. (1995, September). Human figures and the DIS protocol: An analysis. Proceedings of the 13th Workshop on the Interoperability of Distributed Interactive Simulations. [On-line] Orlando, FL: Available: http://ftp.sc.ist.ucf.edu/STDS/workshop/13th/papers/128.doc.

Naylor, S. D. (1996, June 10). 'Next' up: Looking beyond Force XII. Army Times, p. 18.

Neisser, U. (1976). Cognition and reality: Principle and implications of cognitive psychology. San Francisco: W. H. Freeman.

Orasanu, J. (1995). Evaluating team situation awareness through communication. In D. Garland and M. Endsley (Eds.), Proceedings of the International Conference on Experimental Analysis and Measurement of Situation Awareness (pp. 283-288). Daytona Beach, FL: Embry-Riddle Aeronautical University Press.

Orasanu, J., & Connolly, T. (1993). The reinvention of decision making. In G. A. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok, (Eds.), Decision Making in Action: Models and Methods (3-20). Norwood ,NJ: Ablex Publishing Corp.

Pew R. W. (1995). The state of situation awareness measurement: Circa 1995. In D. Garland and M. Endsley (Eds.), Proceedings of the International Conference on Experimental Analysis and Measurement of Situation Awareness (pp. 7-16). Daytona Beach, FL: Embry-Riddle Aeronautical University Press.

Prince, C., Salas, E., Bowers, C, & Jentsch, F. (1995) Team situation awareness research: Many paths to a destination. In D. Garland and M. Endsley (Eds.), Proceedings of the International Conference on Experimental Analysis and Measurement of Situation Awareness (pp. 129-134). Daytona Beach, FL: Embry-Riddle Aeronautical University Press.

Rasmussen, J. (1986). Information processing and human-machine interaction: An approach to cognitive engineering. New York: North-Holland.

Rinalducci, E. J., Cinq-Mars, S. C., Mapes, D., & Higgins, K. E. (1996). Determining the field of view in HMDs: A psychophysical method. PRESENCE, 5 (3), 353-356.

Salas, E., & Cannon-Bowers, J. A.(September, 1995) Methods, tools, and strategies for team training. In M. A. Quinones & A. Dutta (Eds.), Training for 21st century technology: Applications of psychological research. Washington, D. C.: APA Press.

Salas, E., Dickinson, T. L., Converse, S. A., & Tannenbaum, S. I. (1992). Toward an understanding of team performance and training. In Teams: Their training and performance, R. Swezey & E. Salas, (Eds.), Ablex Publishing: Norwood NJ, 3-55.

Salas, E., Cannon-Bowers, J. A., & Johnston, J. H. (in press). How can you turn a team of experts into an expert team?: Emerging training strategies. In C. Zsambok & G. Klein, (Eds.) Naturalistic decision making. Hillsdale, NJ: LEA.

Salter, M. S., Knerr, B. W., Lampton, D. R., Fober, G F., and Dressel, J. D., (1996). Small team portal into the 21st century -- STP21 (RR 1704). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social and Sciences. (AD A323 581)

Sea Dragon and CMC's Warfighting Lab vision of tomorrow's Marine Corps. (1996). Amphibious Warfare Review. Winter/Spring 96. [on-line]: http://ismo-www1.mqg.usmc.mil/ cwl-main/html/amph96.htm

Shrestha, L. B., Prince, C., Baker, S. P., & Salas, E. (1995). Understanding situation awareness: Concepts, methods, and training. Human/Technology Interaction in Complex Systems, 7, 45-83.

Singer, M.J., Allen, R.C., McDonald, D.P., & Gildea, J.P. (in preparation). Terrain appreciation in virtual environments: Spatial knowledge acquisition (ARI Technical Report). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social and Sciences.

Smith, K. and Hancock, P. A. (1995). Situation awareness is externally directed consciousness. Human Factors, 37(1), 137-148.

Sticha, P.J., Campbell, R.C., & Schwalm, S.R. (1996). Virtual environment interface requirements for combat leader training and mission rehearsal. (HumRRO FR-WATSD-96-15). Alexandria, VA: Human Resources Research Organization.

Sticha, P. J., Singer, M. J., Blacksten, H. R., Morrison, J. E., & Cross, K. D. (1990). Research and methods for simulation design: State-of-the-art (TR 914). Alexandria, VA: United States Army Research Institute for the Behavioral and Social Sciences. (AD A230 076)

Stout, R. J., Salas, E., & Carson, R. (1994). Individual task proficiency and team process behavior: What's important for team functioning? Military Psychology, 6(3), 177-192.

Stuart, R. (1996). The design of virtual environments. New York: McGraw Hill.

Urban, J. M., Bowers, C. A., Cannon-Bowers, J. A., & Salas, E. (1995). The importance of team architecture in understanding team processes. In M. Beyerlein (Ed.), Advances in interdisciplinary studies of work teams (Vol. 2, pp. 205-228). Greenwich, CT: JAI.

Urban, J. M., Bowers, C.A., Monday, S.D., & Morgan, B.B. (1995). Workload, team structure, and communication in team performance. Military Psychology, 7(2), 123-139.

Virtual Space Devices, Inc. (1996). Virtual Space Devices, Inc. [On-line] Available: http://www.vsdevices.com.

Wason, P. C. (1960). On the failure to eliminate hypotheses in a conceptual task. Quarterly Journal of Experimental Psychology, 12, 129-140.

Weiner, E. L. & Nagel, D. C. (1988). Human factors in aviation. San Diego: Academic Press.

Wellens, A. R. (1993). Group situation awareness and distributed decision making: From military to civilian applications. In N. J. Castellan (Ed.), Individual and group decision making (pp. 267-292). Hillsdale, NJ: Hove and London.

Wickens, C.D., & Baker, P. (1995). Cognitive issues in virtual reality. In W. Barlow and T.A. Furness (Eds.). Virtual environments and advanced interface design (pp. 514-542). New York: Oxford.

Youngblut, C., Johnston, R.E., Nash, S.H., Wienclaw, R.A.,& Will, C.A. (1996). Review of virtual environment interface technology (IDA Paper P-3186). Alexandria, VA: Institute for Defense Analysis.

APPENDIX A

ACRONYMS AND ABBREVIATIONS

AAR...............After Action Review
AMTEP..........Army Mission Training and Evaluation Plan
ARI.................US Army Research Institute for the Behavioral and Social Sciences
ARTEP...........Army Training and Evaluation Program
ATAFS...........Automated Training Analysis and Feedback System
CALL............Center for Army Lessons Learned
CCTT SAF ....Close Combat Tactical Trainer SAF
CGF...............Computer Generated Forces
CIC.................Combat Information Center
DI...................Dismounted Infantry
DIS.................Distributed Interactive Simulation
DSS................Dismounted Soldier Simulation
HMD..............Head-Mounted Display
ICS.................Individual Combatant Simulation
IC SAF...........Individual Combatant SAF
I/O.................Instructor/Operator
IST.................Institute for Simulation and Training
LCD...............Liquid Crystal Diode
ModSAF.........Modular SAF
NDM..............Naturalistic Decision Making
NTC...............National Training Center
SA..................Situational Awareness
SAF................Semi Automated Forces
STP-21...........Small Team Portal 21
STRADIS ......Simulation and Training Aid for the Dismounted Soldier
TACT............Team Adaptation and Coordination Training
THP................Take Home Package
TRADOC.......U.S. Army Training and Doctrine Command
TTES SAF .....Team Tactical Engagement Trainer SAF
UPAS............Unit Performance Assessment system
VE..................Virtual Environment(s)
VR..................Virtual Reality